Assessment in Tertiary Mathematics

by

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Introduction

There is a growing consensus among many educators that the goals of teaching and learning mathematics are to help students solve real-life problems, participate intelligently in daily affairs, and prepare them for jobs (Gardiner, 1994; Roeber, 1995). These goals suggest that the role of routine procedural skills should be diminished while more emphasis ought to be placed on learners gaining conceptual insights and analytical skills that appear essential in real-life mathematical problem solving (Schoenfeld, 1993; Stenmark, 1989).

This change in emphasis from routine procedural to conceptual, analytical and critical thinking skills appear to be due the fundamental changes that have occurred in mathematics education generally (Tularam, 1997). The earlier and more traditional theories have been challenged by the modern constructivist's theory. The modern theory suggests that students construct new knowledge through meaningful learning, that is, new knowledge is integrated with related prior knowledge. If new knowledge is not meaningfully related to earlier knowledge then learning may not occur.

Given that the learning environment and context has changed over time, teachers may need to change their previously held beliefs regarding learning and assessment to make learning meaningful. For example, Roeber (1995) argued that it is not possible exclusively use an expository style and expect to achieve the standards of the past. He argued that student learning styles such as audio, visual, and kinetic learning styles need to be accommodated in intructional environments for learning to become meaningful. Indeed, there are a number of implications of the modern view of learning and teaching of mathematics but this paper only explores the implications related to the assessment of mathematical learning based on the constructivists' standpoint.

Assessment and Evaluation

The assessing of students seems to be a necessary aspect of most teaching situations. O'Day and Smith (1993:1) advocated that "assessment is important because it is believed that what gets assessed is what gets taught". It seems that the main purposes of assessment are to make instructional decisions and to monitor student progress. Such assessment and monitoring may be conducted in a well structured and formal manner or the assessment process may be conducted in a less formal and structured manner. Whatever form the assessment may take,

the assessment procedure appears to be important and thus learners need to be subjected to some form of assessment.

There is some evidence that students in the tertiary sector are not performing to required standards. For example, the American research findings suggest that higher education is not preparing their graduates for today's needs (Gardiner, 1994). In the main, the universities are not equipping students with general mathematical thinking and reasoning skills. One of the areas that American policy makers have focused upon to deal with this aspect is assessment and evaluation.

Types of Assessment and Evaluation

There are a number of types of evaluations. For example, to examine progress in student learning a student evaluation is required while to examine the effectiveness of school programs a program evaluation is necessary; and to examine the effectiveness of the curriculum a curriculum evaluation program is required. Instructors may also reflect on the effectiveness of their instruction in which case a teacher self-evaluation is appropriate. Therefore, assessment and evaluation need to be based on the prescribed needs of the program itself. In this paper, the focus is only on the current trends in student evaluation techniques. The words assessment and evaluation will be used interchangeably in this paper.

Research on Assessment and Evaluation

The research on assessment and evaluation suggest that a broader range of attributes needs to be assessed and evaluated than has been considered in the past (Stenmark, 1989). In other words, instructors need to evaluate students on a wide range of learnings through the use of a number of assessment strategies. Some of these techniques promoted include non-traditional tasks such as participant observation, conferencing, oral/verbal assignments and real-life application projects. Other assessment techniques being considered are short-answer situations that are open-ended; extended-responses that are open-ended; individual interviews; performance events; performance tasks in which students have extended time, projects; portfolios; and anecdotal records, in addition to multiple-choice exercises.

It seems that in the past, the assessment procedures were driven solely by the curriculum. In most instances, the assessment and evaluation procedures were not specifically related to instructional methods. In contrast, the current literature on constructivism seems to deemphasise the distinction between assessment and instruction. For example, O'Day & Smith (1993:1) argue that "the format of assessment influences the format of learning and teaching". As noted earlier, the main purposes of assessment are to make instructional decisions and to monitor student progress. Assessment and evaluation of student progress may help determine whether the instructor's intended meaning is the same as the student's constructed meaning. It seems then that the purposes of assessment and instruction overlap and thus it can be argued that assessment should be integrated into instruction. In this way, assessment and evaluation would influence instruction and that assessment process would become a useful method for improving instruction.

Affective Issues in Assessment and Evaluation

Student predispositions such as attitudes, beliefs, confidence and motivation are also believed to be important issues in problem solving (Rubenstein, 1975; Tularam, 1997). As early as the seventies, Rubenstein argued that attitudes and dispositions--including persistence are an important part of creative inspirations and problem solving. Importantly, the results of many studies conducted in more recent times suggest that self-regulation and reflection, and logical reasoning are encouraged when students approach learning environments with a "prepared frame of mind", that is, with a creative spirit or a "motivated mind" (Schoenfeld, 1985, 1998; Tularam, 1997).

One of the reasons for the low level of performance of many students in tertiary mathematics may be related to their attitudes, work habits and motivations. There is some anecdotal evidence of low attitudes and motivation in the tertiary sector in Australian universities. Gardiner (1994) reported that American students generally fail to demonstrate study habits and motivation levels that are required for success in tertiary studies.

It seems that the affective domain development is also an important aspect of assessment and evaluation because the domain is closely related to performance levels. One way to make it an important focus of mathematical learning is include factors such as beliefs, attitude and persistence as assessable items in tertiary mathematics. In the main, affective factors may be assessed through interviews and observations (Tularam, 1997). However, projects and assignments may also be critically examined with an affective focus.

Due to a number reasons the affective domain has been neglected in the past. However, it may be argued that the nature and the amount of study tertiary students are willing to engage in may change in a positive sense if affective factors were given prominence in assessment items (Tularam, 1997).

Independent and Group based Assessment

Reflecting the change in emphasis from procedural to conceptual and analytical, assessment items should provide students opportunities to independently demonstrate abilities to critically think and reason. While there will always be a place for independent assessment task, the modern theory suggests that group assessment tasks should also be utilised. Assessment tasks that involve group work require cooperative problem solving that in turn process in turn encourages tolerance. Moreover, the research on critical thinking literature suggests that group work provide students the opportunity to think critically and metacognitively; that is, the group problem solving processes encourages argumentative reasoning, planning, self-monitoring and evaluation (Schoenfeld, 1985). In this way, group based assessment tasks also become learning tasks and thus influence the learning process.

Additionally, group problem solving may allow instructors to assess students' affective traits such as beliefs, attitudes, confidence and motivation towards mathematics.

There is another benefit of group based projects, seminars and written work type tasks. These tasks tend to include a communication component and communication in mathematics is becoming an important issue in education generally. For example, high school mathematics courses now include communicating ability as an important aspect of performance criteria in mathematics. Including this aspect in the tertiary area may make students value communication skills as an important aspect of learning higher mathematics. In turn, students may then appreciate the need for logical development of arguments in their presentations of mathematical work.

Suggested Assessment tasks for Tertiary Mathematics

As noted earlier, in addition to the close relationship between assessment and instruction, the research literature suggests that student evaluation ought to be conducted using a variety of assessment tasks (Mumme, 1990).

The assessment tasks in general may be of the type that test student's ability to (i) formulate problems; (ii) devise plans; (iii) evaluate/interpret the results of analysis and solutions (California Department of Education (CDE), 1989). If assessment items are planned using this framework then the tasks would provide students opportunities to think for themselves; and to express mathematical ideas that are consistent with their mathematical development. In this manner students learn to construct their own responses instead of choosing a single answer.

The types of assessment tasks selected ought to allow learners to demonstrate the depth of their understanding of a problem situation. An in depth understanding is less likely to be assessed with the use of multiple-choice type items or traditional computational questions, while an interview or a project including a written report component type task may highlight the depth and breadth of student's knowledge.

The assessment tasks should encourage students to solve problems using a variety of techniques such as with the use of computer based methods. The learning of mathematical computational software should be emphasised in tertiary mathematics courses and assessment tasks should be based on the use of them.

Group projects, verbal presentations and seminars are also useful strategies and should be utilised as assessment items. Such tasks may allow instructors to examine students' communicative ability, their confidence and attitudes, as well as the ability to cooperate and work with peers.

However, the close relationship between assessment and learning suggests that the tasks considered here are only going to be effective assessment tools if the lecturers and tutors use the tasks to monitor student progress and subsequently adjust their teaching accordingly. Indeed, instructors need to provide learning and assessment environments that encourage students to engage in risk taking, questioning, brainstorming and discussion.

Concluding comments

There are a number of changes that may need to be made in the tertiary sector of education if university mathematics educators are to be in line with current trends in education. Some of the reasons for the changes have been advanced in this paper but detailed understanding of the motivations behind the change in focus would require reading of relevant texts on constructivism and authentic methods of assessment. There seems to be a number of advantages in using the new assessment methods. One relates to the issues of access and equity. The variety of assessment items may accommodate student preferred learning styles. Another relates to the inclusion of aspects of the affective domain that has been ignored even though they are an important aspect of learning mathematics. The new assessment approach takes into account affective factors by placing emphasis on groups, cooperativity. Interestingly, Linn (1987) and Madaus (1985) advocated that the changes in assessment will probably change the way institutions are organised. Will it be possible for us to change the traditional focus and meet this new challenge?

References

California Department of Education (CDE) (1985) *Mathematics framework for California public schools, kindergarten through grade twelve*.Sacramento

California Department of Education (CDE) (1989) *A question of thinking: A first look at students' performance on open-ended questions in mathematics*. Sacramento

Darling-Hammond, L. and A. Wise (1985). Beyond standardization: state standards and school improvement. *Elementary School Journal*, 85, 315-36.

Darling-Hammond, L. (Spring, 1994). Performance assessment and educational equity. *Harvard Educational Review*, 64 (1): 5-29.

Gardiner, L. F (1994). *Redesigning Higher Education. Producing Dramatic Gains in Student Learning*. ERIC Digest. ED394441

Stenmark, J. K. (1989) *Assessment alternatives in mathematics, An overview of assessment techniques that promote learning*. Berkeley: EQUALS and the California Mathematics Council.

Linn, R. (1987). Accountability: The comparison of educational systems and the quality of test results. *Educational Policy*, 1(2): 181-198.

Madaus, G. (1985). Public policy and the testing profession-you've never had it so good? Educational Measurement: *Issues and Practices*, 4 (1): 5-11.

Mumme, J. (1990) Portfolio assessment in mathematics, California Mathematics Project, Santa Barbara.National Council of Teachers of Mathematics (1989) *Curriculum and Evaluation standards for school mathematics*, Reston, VA.

National Center on Education and the Economy (1989). *To secure our future: The federal role in education*. Rochester, NY: Author.

National Council of Teachers of Mathematics. *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author, 1989.

Oakes, J. (1985). *Keeping track: How schools structure inequality*. New Haven: Yale University Press.

O'Brien Pride, T., S. Vokos, and L.C. McDermott. (in press). The challenge of matching learning assessments to teaching goals: An example from the work-energy and impulse-momentum theorems. *American Journal of Physics*.

O'Day, J.A. and M. Smith (1993). Systemic school reform and educational opportunity. In S, Fuheman (Ed.), *Designing coherent educational policy: Improving the system*. San Francisco: Jossey-Bass, pages 250-311.

Roeber, E. (1992). 1. *Developing the comprehensive assessment system: A. top down, B. bottom up, C. both, D. none of the above*. Paper presented at the 1992 Education Commission of the States Conference on Large-Scale Assessment.

Roeber, E. (1995). *Emerging Student Assessment Systems for School Reform*. ERIC Digest. ED389959

Schoenfeld, A. H. (1985). *Mathematical problem solving*. Orlando, FL: Academic Press.

Schoenfeld, A. H. (1998). Reflections on a course in mathematical problem solving. In Alan H. Schoenfeld, James J. Kaput, & Ed Dubinsky (Eds.),*Research in Collegiate Mathematics Education*, Volume III (pp. 81-113). Washington, DC: Conference Board of the Mathematical Sciences.

Schoenfeld, A. H., Minstrell, J., & van Zee, E. (1996). *The detailed analysis of an established teacher carrying out a non-traditional lesson.* Paper presented at the annual meeting of the American Educational Research Association, New York, April 8-12, 1996.

Schoenfeld, A H., Smith, J. P., & Arcavi, A. A. (1993). Learning. In R. Glaser (Ed.), *Advances in Instructional Psychology* (Volume 4, pp. 55-175). Hillsdale, NJ: Erlbaum.

Steinberg, R., G. Oberem, & L.C. McDermott (1996). Development of a computer-based tutorial on the photoelectric effect. *American Journal of Physics*, 64 (11), 1370.

Smith, M. and M. Cohen (September 1991). A national curriculum in the United States? *Educational Leadership*, 49 (1): 74-81.

Tularam. G. A. (1997). *The role of higher-order thinking, algebraic knowledge and affective factors in novel algebraic problem solving.* Unpublished PhD Thesis. Queensland University of Technology, Brisbane.

U.S. Department of Labor (1991). *Secretary's commission on achieving necessary skills.* Washington, D.C.: Government Printing Office.